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Abu Hayat Md. Saiful Islam "Impact of Technological Innovation on the Poor – Integrated Aquaculture - Agriculture in Bangladesh", University of Bonn/ ZEF, 2015

Summary

Many of the poor and vulnerable rely heavily on the agricultural sector. The agricultural sector is typically dominated by crop production, especially the production of rice in Asia. Although the rice production has increased substantially since the onset of the GR, due to rising food demand it is estimated that production needs to increase by more than 50% over the next few decades (Spielman and Pandya-Lorch, 2009; Mishra and Salokhe, 2010). Current concerns about the environment and food security, and food safety, are gaining momentum, which feed the debate about the sustainability of GR approaches in developing countries (Redc1ift, 1989; Alauddin and Tisdell, 1991; Shiva, 1991; Singh, 2000; Kunio, 2002). Horizontal expansion of arable land is not possible in many areas and in some cases it is dec1ining. Thus the only possible way to increase the productivity of land, labour and water resources is vertical intensification through the integration of different agricultural enterprises or by changing management practices and efficiency through sustainable intensification and resource reallocation.

Integrated aquaculture-agriculture (IAA) farming systems could provide such a tool for increasing carbohydrate and protein production more sustainably by using scarce land and water resources in an intensive and complementary way (Meaden and Kapetsky, 1991). Several studies in different countries have .identified the advantages of IAA in terms of a more efficient use of land and water resources, an increased food and fish production, a greater food and nutritional security, an improved farmer income (Mukherjee, 1995; Gupta et a1., 1996, 1998; Purba, 1998; Horstkotte-Wesseler, 1999; Berg, 2002; Ahmed et a1., 2008; Nahar, 2010; Ahmed and Garnett, 2011; Rahman et al., 2011), and of the control of rice weeds, pests, and mosquitoes (Neng et a1., 1995; Rothuis et a1., 1998; Vromant et a1., 1998; Berg, 2001; Ichinose et a1., 2002; Frei and Becker, 2005). In spite of these immense benefits and the research and promotional efforts of many international and national organisations, IAA farming has not been widely adopted in Asia (Rothuis, 1998; Ahmed et a1., 2008). This issue elicits the question of whether or not the adoption of IAA and its impacts are adequately understood.

Most of the published and unpublished researches on IAA farming are incomplete. There is a general lack of high quality detailed field research using scientific and proper econometric methods addressing the impacts of IAA on poverty, food security, gender and other aspects, as well as the effects on extremely poor and marginalised populations settings. Research on rice-fish based IAA has focused primarily on biological and technical issues that are location and season specific rather than at the system level or across entire annual agricultural cyc1es. Socio-economic, policy, and institutional dimensions of rice-fish based IAA system research

are generally lacking (Dey et a1., 2013). Thus there is a need to systematically examine these issues before a widespread diffusion of IAA farming into other areas of the world, inc1uding Bangladesh. Doss (2006; 208) mentioned that technology adoption studies did not fully consider "[t]he issues of how institutional and policy environments affect the adoption of new technologies and how the dynamic patterns of adoption affect the distribution of wealth and income". Given this backdrop, this study attempted to fill research gaps by using more sophisticated analytical approaches based on an integrated value chain conceptual framework and panel data under a broader range of geographical and institutional conditions in marginalised and extreme poor indigenous community settings in Bangladesh. Thus it is expected that the study will facilitate the ability of policy-makers and international development organisations to make more nuanced decisions about the optimal entry point for addressing rural poverty, food and nutrition security and assessing approaches to rural development as well as their effectiveness in reducing rural poverty and improving food and nutrition security in Bangladesh. The study examined causality among factors that affect IAA value chain participation and its impacts in terms of welfare and the environment. Externalities of system changes were explicitly modelled (i.e. welfare benefits, environmental benefits or costs). Specifically, the study sought to answer the following research questions:

1. Is participation in IAA value chains a profitable option and how can overall performance be improved?
2. What are the factors affecting the decision of whether or not to participate in IAA value chains and how do these factors differ among the participator categories?
3. How do IAA value chain participation dynamics affect the welfare of the marginalized rural poor?
4. How do farmers perceive the environmental effects of rice-fish based IAA diffusion relative to rice monoculture and the factors determining such perceptions?

The study used household-level three-wave panel data and cross-sectional survey data from indigenous households in the plains of northern and north-western Bangladesh. The study area included three districts (10 sub-districts) in the north and two districts (four sub-districts) in the northwest. Most of the study area is near the border and rural, where normally the indigenous people of Bangladesh reside. Among the three wave panel survey, the first and second survey rounds were conducted in 2007 and 2009 respectively under the supervision of WorldFish (WF) Bangladesh researchers. The third survey round (re-visited) was conducted from July 2011 to January 2012 by the author himself with the assistance of trained enumerators. The study sites were deliberately sampled from the Adivasi Fisheries Project (AFP) sites.[1] A multistage sampling procedure was applied for the survey effort. At the beginning of the AFP in 2007, WF conducted a census of 5337 Adivasi households across five districts in northern and north-western Bangladesh. Out of the total sample, 3594 extremely poor households (based on wealth ranking) were selected from 120 communities for intervention (treatment) by the project. A total of seven suitable livelihood intervention options within the IAA value chain were disseminated among the selected households according to their resource base, and social and economic characteristics such as income, land holding size, and food security status. Among the selected households, those that were relatively wealthier and that own or have access to suitable assets for fish culture (Le. ponds, rice fields,

[1] The project was implemented by WorldFish and its partner organizations from 2007 until 2009 to increase food security and dietary nutrition by diversifying livelihood options among resource-poor, marginalized Adivasi (indigenous) communities (see Pant et al, 2014),

community aquatic resources) were engaged in IAA production related value chain interventions. The relatively poorer households, such' as those that were landless or that lacked significant physical or economic resources, were selected for inclusion within upstream and downstream IAA value chain activities such as fingerling or fish traders and fishermen (netting). Entire sample households received technical training through a 'farmer field school' (FFS) and initial financial support (AFP, 2010; Pant et al., 2014).

To assess the nature and extent of changes resulting from the IAA value chain participation; WF Bangladesh conducted a random survey with 510 of the participating households and 147 non-participating households (control) in 2007 (first round of survey) and a follow-up survey (the second round of survey) with the same households in 2009 to monitor impacts at the household level. The author revisited the same households in 2012 (the third round) and surveyed a sub set of 450 participating households and 121 non- participating households. In addition to the questions asked in the first two survey rounds, in the third round, the author included detailed questions on production, revenues, and perceptions of the social and environmental impacts of rice-fish based IAA and rice monoculture systems. The sample for the third survey round included an additional 133 nonindigenous rice monoculture farmers. Table 1 describes the sample and dynamics over time. Based on data from the third survey round, it is evident that the IAA value chain participating households split-up into two groups, those that continued participation in IAA value chain activities (234 households) and those that had abandoned participation in IAA value chain activities (216 households). This reflects the dynamics of IAA value chain participation. In this study we explored the factors that determine participation dynamics and welfare impacts. This appears to be the first analysis of long-term panel data on IAA systems that considers all value chain actors. Between the first and second survey round there was no sample attrition, but between the second and third round there was some sample attrition, which is normal for long-term panel surveys. The sample attrition in the third survey round was 13.1 %. We tested for attrition bias and found that it was random. Due to migration, death, and regular absence from home, some sample households from the· first and second survey round could not be included in the third survey round.

Table 1 Sample size of the panel survey of IAA participator and non-participator

Survey round	Year	IAA value chain non-partici-pators	IAA value chain partici-pators	IAA value chain dis-partici-pators	Total	Attrition (%)	Additional sample
1st Wave	2007	147	510	-	657	-	-
2nd Wave	2009	148	509	-	657	-	-
3rd Wave	2012	121	234	216	571	13.09	133

Financial performance of the value chain actors was measured using a gross margin analysis. Partial budget analyses were conducted for two rice production systems; a conventional system based on GR strategies (monoculture model) and a system based on diversification through aquaculture (integrated farm model). We applied a SWOT analysis to better understand relevant issues including policy and institutional level strengths, weakness, opportunities and threats that can affect future strategy building regarding rice-fish technology adoption and diffusion. The findings indicate that integrated rice-fish systems offer considerable potential for increasing overall agricultural productivity and farm incomes in

Bangladesh. The results also show that there are opportunities for extreme1y poor and landless households to participate in the rice-fish based IAA value chains in a profitable manner. The findings demonstrate that rice-fish based IAA can create profitable business opportunities along the value-chain and employment opportunities for women, especially in production related activities. The partial budgeting analysis results corroborated that rice-fish based IAA systems offer an economically competitive alternative to rice-monoculture in Bangladesh. As a technologically innovative agricultural approach, integrated rice-fish production faces a number of significant challenges such as a lack of government support and high start-up costs in terms of land, labour, fingerlings, feed, and the required modifications to existing rice production that hinder 'pro-poor' adoption and diffusion. In the short ron, upstream and downstream rice-fish value chain actors have fewer entry barriers; in the long run, despite high initial costs of rice-fish production the benefits can be significantly higher for poor farmers.

Technology adoption is a dynamic process, but the underlying dynamics have seldom been studied using empirical approaches. In contrast, we examined IAA value chain participation dynamics and the factors that distinguish among non-participators, continuous participators, and those who begin but later discontinue participation (dis-participators) using different panel estimation methods (e.g. multinomial logit, random effects (RE), and correlated random effects logit regression analyses) to control for omitted variables and endogenous regressors that very often are not possible to identity or may be ambiguous from cross-sectional studies. The factors that influence both the IAA value chain participation and the subsequent abandonment have rarely been addressed in technology adoption literature. initially we used the panel data to expand the typical comparison of 'participators' / 'adopters' and 'non-participators' / 'non-adopters' to a more nuanced multinomial logit analysis of 'nonparticipators,' 'participators,' and 'dis-participators.' The multinomial logit model, as specified, also partially addresses the endogeneity issue by using explanatory variables from the baseline to describe the IAA value chain participation process from the baseline until the current period (2007-2012). The results revealed significant differences among participator categories (continuous participators and dis-participators) and non-participators, but few differences between 'participators' and 'dis-participators'. We then used the panel data to estimate three random effect (RE) logit models (i.e. RE logit, lagged RE logit and correlated random effects logit models) that control for fixed and random omitted variables and endogenous regressors. The results are consistent with determinants cited in the literature; more educated and larger households with better access to extension services and market information that participate in community-based organisations (CBO) are more likely to participate and continue participating in IAA value chain activities. Importantly, farm size and farm income did not appear to be positive significant determinants of IAA value chain participation, suggesting that IAA value chain activities are appropriate for resource-poor households. The results also indicate that distinct factors were associated with continuous participation and dis-participation in IAA value 'chain activities, especially for actors involved in upstream and downstream' value chain activities. Important determinants of dis-participation were the age of household heads, the number of assets, the farm size, the fisheries income, and non-farm income. The probability of participating in IAA value chain activities increases significantly with education, and together with greater CBO membership and access to extension services and market information that confirm the broader positive effects of technical knowledge and human capital development on value chain participation.

Welfare impacts of IAA participation dynamics were estimated through different specifications (e.g. POLS, RE, FE, Heckit and Control function approaches) under different assumptions to control for unobserved heterogeneity and endogenous selection of IAA value chain

participation dynamics. Beginning with a naive pooled ordinary least squares (POLS) estimation that assumes that participation and dis-participation in IAA value chains are exogenous, we further controlled for unobserved heterogeneity and endogenous selection. The results validated as well as added to the current understanding of technology adoption. Additionally, we applied fixed effect (FE) specifications to sample households disaggregated by production related actors (that participated in production related IAA value chain activities that require land) and the non-production value chain actors (extremely poor households, most of which do not have access to land), to explore the distribution of IAA value chain participation benefits among all IAA value chain actors. The results of the impact analyses of the IAA value chain participation dynamics are robust across specifications, thereby justifying concerns about unobserved heterogeneity and endogenous selection with respect to IAA value chain participation. There is consistent evidence of a positive relationship between IAA value chain participation and household income and the consumption frequency of important food items such as fish and pulse. The results also indicate that these positive income effects increased over time and that IAA value chain participation benefits were comparatively higher for the relatively wealthier households that participated in production related value chain activities. Considering participation dynamics, abandonment of IAA value chain participation (dis-participation) negatively impacts household income, which suggests that the decision to discontinue IAA participation is not based on the economic superiority of alternative options, but rather may be due to other IAA value chain participation barriers.

I investigated the comparative impacts of integrated rice-fish systems and rice monoculture systems on socio-environmental variables by exploring farm level environmental input use and farmer perceptions, and conducting an extensive literature review. To date there do not appear to have been any attempts to examine the socio-environmental performance of integrated rice-fish production relative to rice monoculture based on farmer perceptions. The results suggest that rice-fish based IAA is a sustainable alternative to rice monoculture. Although farmers were well aware of the more negative socio-environmental impacts of rice monoculture compared to rice-fish based IAA systems, their perceptions were limited to visible impacts such as the incidence of disease and crop pests, changes in soil structure, the relative quantities of beneficial organisms, soil fertility, fish harvests, etc. We also examined the factors that influence farmer perceptions about the socio-environmental impacts of rice monoculture using a Tobit and PSM approach. The Tobit results show that ethnicity (indigenous or non-indigenous), off-farm income, AFP participation, adoption of integrated rice-fish production, and infrastructure access were the most significant determinants of socio-environmental impacts perceptions. The PSM results further supported the robustness of integrated rice-fish system adoption as a major determinant of farmer awareness of the adverse socio-environmental impacts of rice monoculture. Thus promotion of integrated rice-fish systems, development of better infrastructure, and relevant education through FFS approaches would be expected to enhance socio-environmental awareness and may help reduce the use of environmental hazardous inputs as well as it may improve the adoption rates of integrated rice-fish systems.

Although this study is the first of its kind with respect to consideration of several aspects of technology adoption and its impacts, there are several issues (outline in the future research scope section in the dissertation) which were not considered or were beyond the scope of this research and should be addressed by future research efforts. Overall the results of the study indicate the need to pay broader attention to IAA. Although the results generally reveal that the gains from IAA value chain participation are substantial, many smallholders are unable to participate or cannot sustain participation due to various factors that were also identified in this study. Thus policy and institutional interventions are necessary to stimulate the adoption

and diffusion of IAA among poor smallholders as a means of improving nutrition, incomes, ·and ameliorating poverty.

References

AFP (Adivasi Fisheries Project) (2010). Fisheries and Aquaculture Enterprise Development for Adivasi (Tribai) Communities in the Northem and Northwestem Regions of Bangladesh. The European Union's Food Security Programme for Bangladesh. WorldFish Center

Bangladesh and South Asia office, Dhaka, Bangladesh. Ahmed, N., and Gamett, S. T. (2011). Integrated rice-fish farming in Bangladesh: meeting the challenges of food security. Food Security, 3(1),81-92.

Ahmed, N., Demaine, H., and Muir, J. F. (2008). Freshwater prawn farming in Bangladesh: history, present status and future prospects. Aquaculture Research, 39(8), 806-819.

Alauddin, M., Tisdell, C. (1991). The "Green Revolution" and economic development: the process and its impact in Bangladesh, London: Macmillan Press Ltd.

Berg, H. (2001). Pesticide use in rice and rice-fish farms in the Mekong Delta, Vietnam. Crop Protection, 20(10),897-905.

Berg, H. (2002). Rice monoculture and integrated rice-fish farming in the Mekong Delta, Vietnam--economic and ecological considerations. Ecological Economics, 41(1), 95107.

Dey, M.M., Spielman, D.J., Haque, A.B.M M., Rahman, M.S., and Valmonte-Santos, R. (2013). Change and Diversity in Smallholder Rice--fish Systems: Recent Evidence and Policy Lessons from Bangladesh. Food Policy, 43, 108-:-117. '

Doss, C. R. (2006). Analyzing technology adoption using microstudies: limitations, challenges, and opportunities for improvement. Agricultural Economics, 34(3), 207-219. Frei, M., and Becker, K. (2005). Integrated rice-fish production and methane emission under greenhouse conditions. Agriculture, ecosystems and environment, 107(1), 51-56.

Gupta, M.V., Rahman, M.A., Mazid, M.A., and Sollows, J.D. (1996). Integrated agriculture aquaculture: A way for food security for small farmers and better resource management and environment. In: Heidhues, F. and Fadani, A. (eds.), Food Security and Innovations Successes and Lessons Learned. Peter Lang, Frankfurt. 165-175.

Gupta, M.V., Sollows, J.D., Mazid, M.A., Rahman, A., Hussain, M.G., and Dey, M.M. (1998). Integrating Aquaculture with Rice Farming in Bangladesh: Feasibility and Economic Viability, Its Adoption and Impact (ICLARM Technical Report 55). ICLARM, Penang, Malaysia.

Horstkotte-Wesseler, G. (1999). Socioeconomics 0/Rice-aquaculture and IPM in the Philippines: Synergies, Potential, and Problems. ICLARM Tech. Rep. 57,225 p. http://books.irrLorg/9718020047 content.pdf.

Ichinose, K., Tochihara, M., Wada, T., Suguiura, N., and Yusa, Y. (2002). Influence of common carp on apple snail in a rice field evaluated by a predator-prey logistic model International Journal 0/Pest Management, 48(2), 133-138.

Kunio, T. (2002). Views on food production: towards a new green revolution. Paper prepared for presentation at the 13th International Farm Management Congress, Wageningen, The Netherlands, July 7-12, 2002. http://ageconsearch.umn.edufbitstream/6987/2/cp02ts01.pdf(accessed on 04.02.2012).

Meaden, G. J. and Kapetsky, J. M. (1991). Geographical information systems and remote sensing in inland fisheries and aquaculture: F AO Fisheries Technical Paper 318, Food and Agricultural Organisation, Rome, ltaly.

Mishra, A. and Salokhe, V. (2010). The effects of planting pattern and water regime on root morphology, physiology and grain yield of rice. Journal 0/Agronomy and Crop Science, 196(5),368-378.

Mukherjee, T.K. (1995). Integrated crop-livestock-fish production systems for maximizing productivity and economic efficiency of small holders' farms. In: The Management o} Integrated Freshwater Agro-piscicultural Ecosystems in Tropical Areas (J.J. Symoens and J.C. Micha, eds.), pp. 121-143. Seminar Proceedings, RAOS and CTA, Wageningen, Brussels, Belgium.

Nahar, A. (2010). Impacts of different rice-fish-prawn culture systems on yield of rice, fish and prawn and limnological conditions. Journal 0/ the Bangladesh Agricultural University, 8(1), 179-185.

Neng, W., Guohou, L., Yulin, L., and Gemei, Z. (1995). The role of fish in controlling mosquitoes in rice fields. In Rice-Fish Culture in China (K. T. MacKay, ed.), pp. 213216.

Ottawa: IDRC.
http://www.idrc.ca/ENlResourceslPublications/openebooks/3135/index.html#page 213.
Pant, J., Barman, B.K., Murshed-E-Jahan, K., Belton, B., and Beveridge, M. (2014). Can

. aquaculture benefit the extreme poor? A case study of landless and socially marginalized Adivasi (ethnic) communities in Bangladesh. Aquaculture, 418, 1-10.

Purba, S., (1998). The economics of rice-fish production systems in North Sumatra, Indonesia: An empirical and model analysis. University ofGöttingen, Diss, 188 pp.

Rahman, S., Barmon, B.K., and Ahmed, N. (2011). Diversification economies and efficiencies in a 'blue-green revolution' combination: a case study of prawn-carp-rice farming in the 'gher' system in Bangladesh. Aquaculture International, 19,665-682.

Redelift, M. (1989). The environmental consequences of Latin America's agricultural development: some thoughts on the Brundtland Commission report. World Development, 17(3),365-377.

Rothuis, A.J., Nhan, D.K., Richter, C.J., Ollevier, F. (1998). Rice with fish culture in the semideep waters of the Mekong Delta, Vietnam: a socio-economical survey. Aquaculture research, 29(1), 47-57.

Shiva, V. (1991). The violence oj Green Revolution: third world agriculture, ecology and polities. Zed Books.London.

Singh, R.B. (2000). Environmental consequences of agricultural development: a case study from the Green Revolution state of Haryana, India. Agriculture, ecosystems and environment, 82(1),97-103.

Spielman, D., and Pandya-Lorch, R. (2009). Millions fed: Proven successes in agricultural development. International Food Policy Research Institute (IFPRI). Washington, DC. http://www.ifpri.org/sites/default/files/publications/oc64.pdf (accessed on 15.02.2012).

Vromant, N., Rothuis, A. J., Cuc, N. T. T., and Ollevier, F. (1998). The effect of fish on the abundance of the rice caseworm Nymphula depunctalis (Guenee) (Lepidoptera: Pyralidae) in direct seeded, concurrent rice-fish fields. Biocontrol Science and Technology, 8(4),539-546.

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